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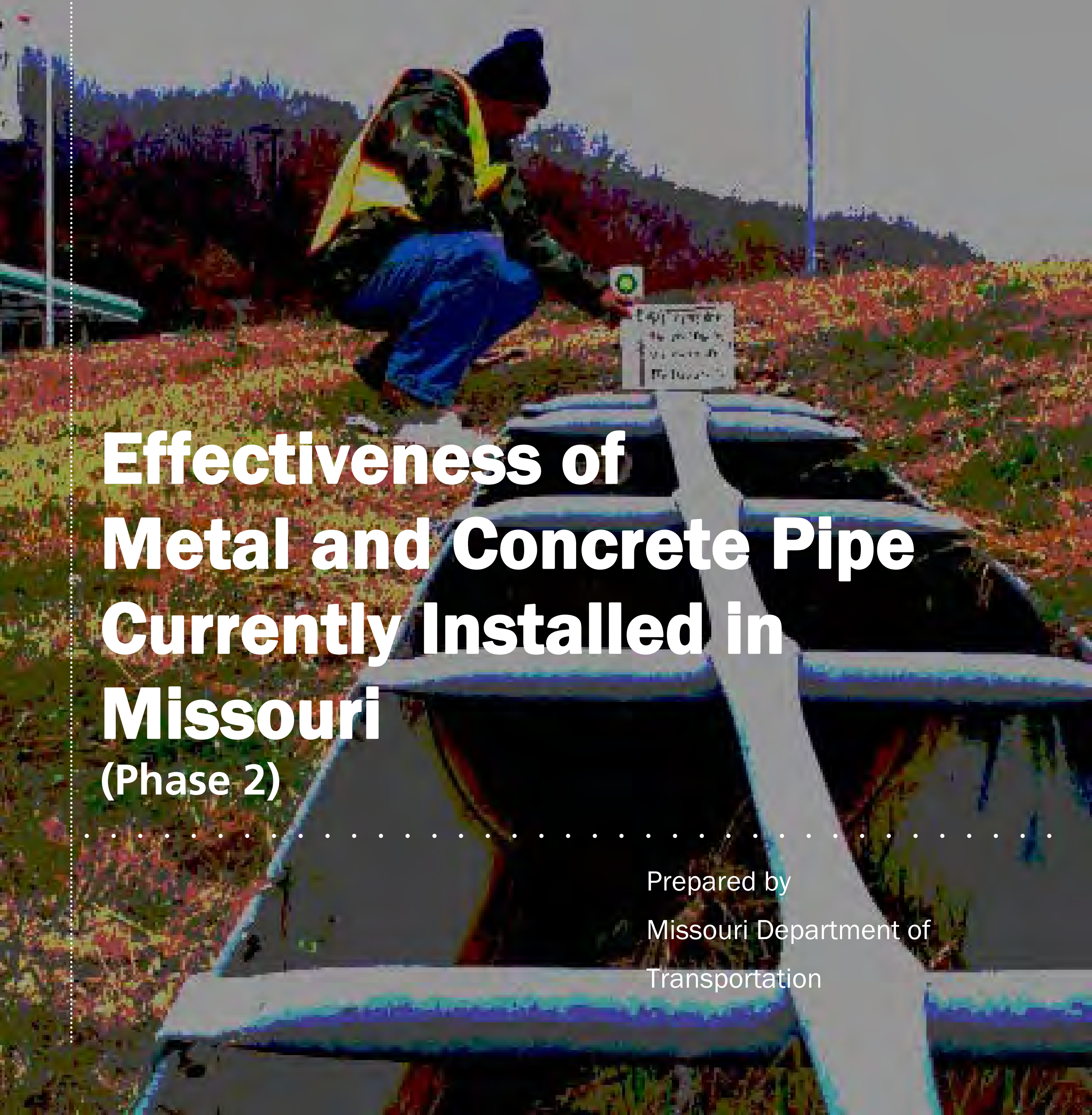

Effectiveness of Metal and Concrete Pipe Currently Installed in Missouri

(Phase 2)

Prepared by
Missouri Department of Transportation

FINAL REPORT

RI07-058

Effectiveness of Metal and Concrete Pipe Currently Installed in Missouri (Phase 2)

Prepared for the
Missouri Department of Transportation
Organizational Results

by
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<tr><td colspan="6">16. Abstract

A review and assessment of the effectiveness of corrugated metal (corrugated galvanized steel, aluminized steel, aluminized-bituminous coated steel, aluminum alloy, epoxy coated steel pipe) and reinforced concrete pipe currently installed on Missouri DOT’s system and of the specifications as written. This report will concentrate on the condition of the pipe with only minor mention of the specification changes made in 2004; a future report will address more fully the specification.</td></tr>
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Executive Summary

A review and assessment of the effectiveness of Reinforced Concrete Pipe (RCP) and Corrugated Metal Pipe (CMP) currently installed on the Missouri Department of Transportation (MoDOT) system and of the specifications as written was requested.

A review was made of 125 culvert pipe, 75 RCP and 50 CMP of different age groups throughout the state (see the table in Appendix 2 for locations.). This study looked at new RCP and CMP (more specifically Group B and Group C pipe per 2004 Missouri Standard Specifications) recently installed on construction projects from 2002 thru 2007.

Also inspected were older installations of RCP and CMP. A few of the oldest concrete pipe inspected were non-reinforced but most were reinforced concrete pipe or RCP. The additional corrugated metal pipe or CMP were mostly zinc-coated or galvanized steel, and some special pipe that were CMP made of Aluminum Alloy, Aluminum-Coated (Aluminized) steel, Polymer Coated (PCO) steel or combinations of galvanized steel, aluminized steel or Polymer Coated steel that were also Bituminous Coated. Most of the pipes picked were previously inspected in earlier MoDOT culvert surveys so that their conditions could be compared over time.

All pipes were visually inspected to determine if any damage, erosion, or abrasion had occurred since it was last inspected. A picture was taken of the inlet and outlet of each pipe. Additional photos of the inside of the pipe were taken at some locations to show the condition of the pipe: cracks, corrosion, open joints, etc. At select culvert locations, where it was surmised there could be a corrosion problem, soil and water pH readings were obtained to document the corrosiveness of the pipe's environment. The condition of the pipe was rated using three criteria: Condition/Durability, Joint & Seam Condition, and Alignment. The ratings were made on a scale of 0-9 similar to the National Bridge Inspection Standard (NBIS) ratings. Pipes were picked with diameters of at least 36", if possible, so that the inspectors could walk or crawl through the pipe.

It was discovered that the concrete pipe or RCP were rated the best and had a service life of 72 years and could easily make the 100 years life originally planned. From past surveys it was determined that the galvanized corrugated steel pipe had a life of about 40 years; this was corroborated by ratings in this survey. The best-rated metal pipe was aluminum alloy, however, there are only a half dozen of these in the state because of their initial high cost. Next best rated is aluminum coated or aluminized steel. The oldest aluminized pipe inspected was 53 years old and still has an average rating of 7.67. Polymer coated and Bitumen coated pipe have not fared as well, they have been used as coatings for galvanized or aluminized steel pipe and in some cases seem to hold moisture and contaminants which have even accelerated corrosion of the underlying steel. The largest problem with RCP pipe is the integrity of the many joints, although on the majority it is usually only end joints that have problems later in their service life. For CMP, joints are also a problem along with alignment. Better preparation of pipe bedding and more care in backfilling operations can reduce these problems. CMP's biggest problem is corrosion; especially in areas backfilled with non-homogeneous materials, in areas of highly acidic soils, or exposed to acid runoff such as in old mining areas in Southwest Missouri. It is suggested that only concrete or plastic pipes be used in this area in the future.

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Effectiveness of Metal and Concrete Pipe Currently Installed in Missouri

Introduction

The Construction and Materials Division requested that a new inspection of culvert pipes on Missouri Department of Transportation's highways be done because of a specification change in 2004. The Standard Specifications were changed from specifying a specific type of culvert pipe to putting all culvert pipes within three groups, Group A, Group B and Group C; from longest design life in Group A to shortest in Group C. It is expected that there will be a cost savings because of this new way of designing and specifying culvert pipe. This inspection was of culvert pipe made of metal or concrete currently installed.

The Materials & Research Division started a formal investigation and inspection of a select number of experimental pipes in 1991 known as RI 91-11, the Culvert Study. During the summer and fall of 1994, research personnel visited maintenance buildings throughout the state trying to locate different pipe materials including polyethylene, aluminized, aluminum, polymer coated, poly-vinyl chloride (PVC) and polyethylene liners, and concrete pipe. Upon locating each site, these pipes were tested and the log mile of the site reaffirmed. A list containing 148 culvert pipes in 55 counties throughout the ten districts was created to sample the performance of various types of pipes. This study was carried out as an annual investigation until 1997. Later, it was decided that the culvert inspections should be performed on a bi-annual basis.

A Culvert Assessment Report was prepared in 2000. The purpose of this report was to assess the importance of the Missouri Department of Transportation's culvert study. This report provided some insight as to what had been accomplished in the past, what was being done then, and what to do in the future. Topics discussed in this report were testing methods, life-cycle cost, quality of different pipe materials, visual inspections, and life span of pipes with respect to environmental conditions.

A diagnostic plot analysis from the 2000 Culvert Assessment Report indicates that pipe installed from the time period of 1900 to 1939, steel pipe lasted approximately 60 years. However, steel pipe installed after 1940 has only lasted about 40 years. Corrugated galvanized steel pipe (GSP or CSP) was originally expected to last at least 50 years. Due to an insufficient number of failed reinforced concrete pipe (RCP), it was not possible to predict its service life. RCP is expected to approach a service life of 100 years.

The other recommendations made in the 2000 report concerned the installation of new pipe. It recommended backfill material used on steel pipe must be homogeneous. Non-homogeneous backfill increases the rate of corrosion. Test sites should be tested for pH, resistivity, moisture content, and sulfate levels before the pipe is installed. This will assist MoDOT in determining the type of pipe to install for the best economical return.

With these recommendations in mind this review was made of a sampling of metal culvert pipe and reinforced concrete pipe statewide were picked to re-inspect in this 2007 study. First, pipe

still existing from the list of site testing data included in the 2000 report were re-inspected. Additional pipe were tested from the old Research, Development and Technology divisions bi-annual Culvert Survey that was based on picking locations from each of the 13 Units (A thru P) of different soil types taken from the U.S. Geological Survey's Surficial Materials Map of Missouri, 1982 by John W. Whitfield. Finally, new construction projects from 2000-2006 were picked to verify installation practices and early performance of pipe from the new Group A, B, C designations put into effect in the 2004 Standard Specifications. Since the 2000 Culvert Study Report determined that none of the previous on site field-testing could in fact reliably predict pipe corrosion, it was recommended not to do any field tests. However, it was decided for this study to take at least soil and water pH samples at few locations that appeared may be causing pipe corrosion and brought them back to the Chemical Laboratory for testing.

Procedures and Inspections in 2007 Metal and RCP pipe Inspection

The testing and inspection aspect of the survey consisted of several components. All pipes were visually inspected to determine if any damage, erosion, or abrasion had occurred since it was last inspected. A picture was taken of the inlet and outlet of each pipe. Additional photos of the inside of the pipe were taken at some locations to show the condition of the pipe: cracks, corrosion, open joints, etc. Pipes were picked with diameters of at least 36", if possible, so that the inspectors could walk or crawl through the pipe. Therefore the department's tracked video camera was not needed and inspection time was saved, as the camera's use is time consuming and the bottom of the inside of the pipe, or flow line or invert as it is called, has to be almost completely free of any debris for it to traverse through the whole pipe length.

Corrugated Metallic-Coated Steel Culvert Pipe (CMP) includes galvanized steel pipe (GSP) which by Section 1020 of the specifications requires, "2.00 ounces psf of double exposed surface of zinc coating, and aluminized steel pipe (ALZ) requiring 1.00 ounces psf of double exposed surface." Also included in metal pipe category was polymer coated steel pipe (PCO) and older installations of bituminous-coated steel pipe (BIT). Finally several Aluminum Alloy culvert pipe (ALU) were also inspected for this report. These CMP pipe usually have no end sections in smaller diameters except that some entrance pipes have been cut on a diagonal to match the slope and concrete poured around them. The larger pipes usually have galvanized steel flared end sections (FES). Concrete pipe dating back to installation in 1935 with most all of them containing steel reinforcement, or reinforced concrete pipe (RCP), were also inspected in this study. Again most of these in the larger diameters have precast concrete FES's and some of the 1950's and 1960's installations have cast-in-place concrete headwalls.

A total of 50 CMP pipes were inspected in six different districts and a total of 76 RCP pipes were inspected in seven districts. Pipes that were in the August 2000 Culvert Study Report were picked out first to inspect in 2007. Of the 117 culvert pipe listed for metal and concrete in the 2000 report, this inspection located and re-inspected 28 as listed in Table 1 below.

Table 1 - Itemized Number of Pipes Inspected as Listed in 2000 Study

Survey Date	2000	2007
Aluminized	25	1
Aluminum	5	5
Polymer Coated	4	2
Galvanized	1	0
Reinforced Concrete	82	20
Total	**117**	**28**

Next culvert pipe were picked from the new inspection criterion set up by six geological regions that were inspected starting from year 2001 –2003. After 2003 it was decided to inspect these same pipe every three years. The inspections were pit on hold in 2006 because of lack of personnel. Inspection sheets rating the culvert pipe from 0 - 9 were established and used for these reports. There were 33 pipes re-inspected from the 2007 study. Actually, only 32 additional pipe were inspected as one on Rt. 43 Newton County (0.22 S Jasper Co Ln) was inspected in 2000 and again inspected in 2003.

Finally, culvert pipe installed on new construction projects let for bid between 2001 and 2006 were inspected to document their condition as new installations and as baselines for comparison to future inspections as they grow older. These projects specifically list the main line cross road concrete pipe as RCP Class III, Cl. IV or Cl. V (their design classification by overfill height or load) not as Group A pipe no matter whether the contracts were let before 2004 or after. However the side road or entrance pipes on projects let with the new 2004 specifications are listed as Group B or Group C pipe. All the Group B pipes that were inspected, except for one RCP pipe in District 8, the contractor picked galvanized steel pipe. A total of 40 pipes were inspected in seven districts. The type pipes are listed for the last three groups in Table 5 in the Appendix. For clarification of how pipes are specified in the 2004 specification presented here is the list from Section 726 – Rigid Pipe Culverts:

> **726.1.1** The contract will specify either the type of pipe or the group of permissible types of pipe. If a group of permissible types is specified, the contractor may use any of the types listed within the specified group as follows:
>
> Group A — Reinforced Concrete Culvert Pipe
> Vitrified Clay Culvert and Sewer Pipe
>
> Group B — Reinforced Concrete Culvert Pipe
> Vitrified Clay Culvert and Sewer Pipe
> Polymer Coated Corrugated Metal Culvert Pipe
> Corrugated Aluminum Alloy Culvert Pipe
> Corrugated Polyethylene Culvert Pipe
> Corrugated PVC Culvert Pipe
> Corrugated Aluminum-Coated Steel Culvert Pipe
>
> Group C — Reinforced Concrete Culvert Pipe

Vitrified Clay Culvert and Sewer Pipe
Polymer Coated Corrugated Metal Culvert Pipe
Corrugated Aluminum Alloy Culvert Pipe
Corrugated Polyethylene Culvert Pipe
Corrugated PVC Culvert Pipe
Bituminous Coated Corrugated Metal Culvert Pipe
Corrugated Aluminum-Coated Steel Culvert Pipe
Corrugated Zinc-Coated Steel Culvert Pipe

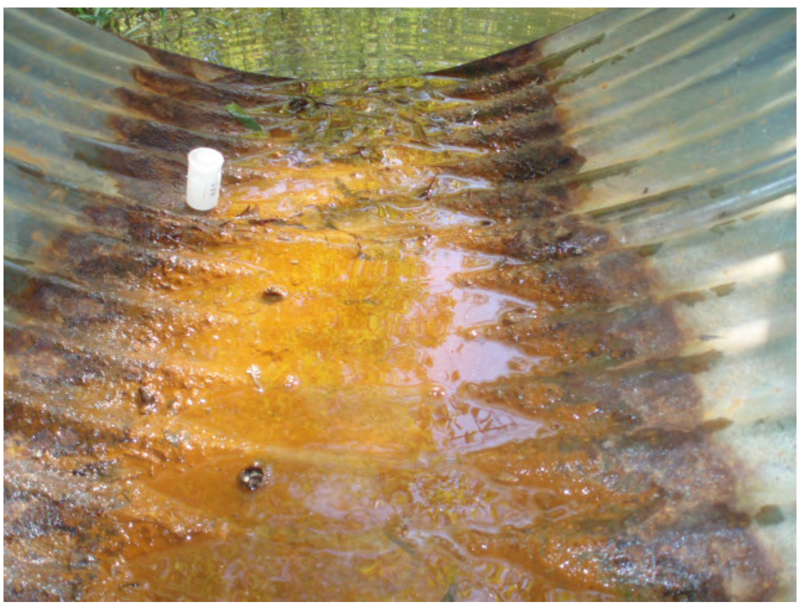
A few CMP and RCP pipes that had locations listed in the two existing databases but had never been inspected were picked. They were picked because of the age range, diameter and length or because the location was convenient while inspecting other pipe nearby. One more new location was added in District 1. While inspecting in Harrison County the local maintenance forces were replacing an old galvanized steel pipe with a new 54” diameter GSP. This new pipe was inspected after it had been backfilled and state Rt. M had been reopened to traffic. There were 26 total first time inspections or “New” pipe inspected (although their ages were not necessarily new).

Pipe Materials and Performance

Field testing was done on a select number of pipe locations for soil and water pH readings. Results from all of the 60 test samples taken, 35 soil and 25 water, showed all but one were pH=6.9 or above or close to neutral, pH=7.0. One water sample from the location of a 60” d. Polymer Coated steel pipe on Rt. B, St. Clair County had a pH = 4.1, very acidic. It is known that in this area there are acidic soils and runoff from old coal and mineral mining areas. Previously metal pipes only lasted up to six months at this location. The subject pipe was installed in 1997 and has a polymer coating called Trenchcoat®. In 1998 it had begun to rust after only one year. The soil pH at that time was 5.7 and the water pH was 3.5. In 2007 that coating was flaking off of the exposed end because of ultra-violet light degradation and it was also starting to fail on the inside bottom of the pipe or invert and was rusting about 2 ft. wide. Some of the metal was just beginning to rust, it is estimated that there is perhaps 10% section loss. The pipe is exposed to the acid runoff now and that will accelerate the rate of corrosion. This culvert is in an area that District 7 knows the surface soils are in Pennsylvanian strata that produces highly acidic conditions. The District has tried many products with the goal to reduce costs below the replacement cost of reinforced concrete pipe. Concrete pipe has been observed in past MoDOT surveys to also be attacked by the acid runoff causing scaling of the concrete but this is at a much slower rate than corrosion of metal pipe.

The inspection photos from the pipe mentioned are shown below. All the pH results are shown and compared with others in the same area from the 2000 report in a table in Appendix 3.

60" PCO pipe, Rt. B St. Clair Co., 4.5 miles W. Rt. 13, installed 1997. Polymer coating flaking off exposed end of pipe due to UV rays.



60" PCO pipe, Rt. B, St. Clair Co., Polymer Coated CMP placed in 1997, invert rusted and pitted, 10% section loss in 10 years.

Corrugated Metal Pipe Inspection

A total of 50 CMP culverts were inspected in six different districts. The majority were galvanized (zinc coated) steel pipe installed from 1950 to present. The problem with steel pipe is that it is susceptive to corrosion and abrasion. The reasons for replacing a GSP are categorized as rusted, crushed, or undermined. The pipe could be replaced for a combination of these reasons. According to Missouri data, seventy-six percent of the pipes were replaced due to rusting alone. Therefore, the culvert data indicates that most of the metal pipes are replaced because of corrosion. There are many factors that affect the corrosion of steel; for instance, soil pH, water pH, soil resistivity, coal mining areas, deicing road salts, non-homogeneous backfill material, ground water, and surface water.

Aluminized Pipe

Of eight aluminized steel pipe installed from 1952 thru 1993 five had rusting problems, they were all in District 7 in Barton and Vernon counties and all had a bituminous coating applied to them when manufactured. Inspection photos of one of these pipes in Barton County with a rusted out invert are shown below. The original Aluminized pipe installed in 1952 in District 1 in Nodaway County has only some minor pitting.

Rt. P, Barton Co., 1960, 48" Bit/Alz pipe, Bitumen and Aluminum coating worn off – invert rusted out. Water sample pH=7.2 but must have been low pH runoff in past.

Rt. 246, Nodaway Co., 36"d. ALZ – Original aluminized pipe installed in 1952 with only minor pitting of coating and staining at invert.

Aluminum Alloy Pipe

The three Aluminum Alloy pipe installed in 1962 and 1974 showed only a slight discoloration to brand new appearance or no corrosion at all. One of the aluminum alloy pipe was installed in Barton County in 1962 where the four bitumen coated aluminized pipe that have rusted out are located.

Rt. NN, Barton Co., 1962, 24" Aluminum Alloy – One end mower damaged, stained but no corrosion on invert.

Galvanized Steel Pipe

There were 11 out of 41 existing galvanized steel pipe tested that the invert was beginning to show significant section loss of metal or was completely rusted out, the date installed ranged from 1960 to 1998.

Rt.119, Dent Co., 36" Helical Galvanized Steel – installed 1995 and invert already rusted out the whole length.

Dekalb Co., Rt. D, 48” d., Helical GSP, installed 1998 – invert rusting and pitting, nine years old.

Problems found in the newer galvanized steel pipe (GSP), installed both by construction and maintenance personnel resulted from backfilling with improper materials or without proper compacting practices. The problems seen on new construction jobs were severe deflections and denting or penetrating of the pipe wall with rocks or other pointed objects.

CMP are now most commonly made with small width sections with crimped joints that have the corrugations helically wound into them instead of the old practice of riveted plates. This may be part of the reason that makes it very critical to use best practices when placing and backfilling these pipe. The vertical deflection or squashing of the pipe seen on construction and maintenance installations is caused either by poor backfilling and compacting practices, which may show up right away or over several years in place, or from insufficient overfill height. However it can not be spelled out that some of the deflection problems were not caused by the pipe simply being designed to the minimal thickness or gauge of metal so that there is no safety factor to account for any irregularities when the pipes are installed.

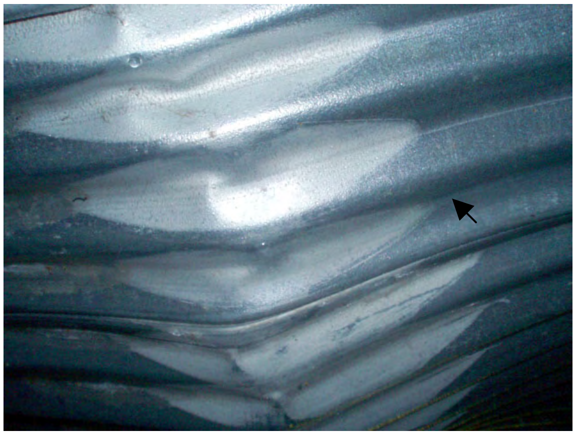


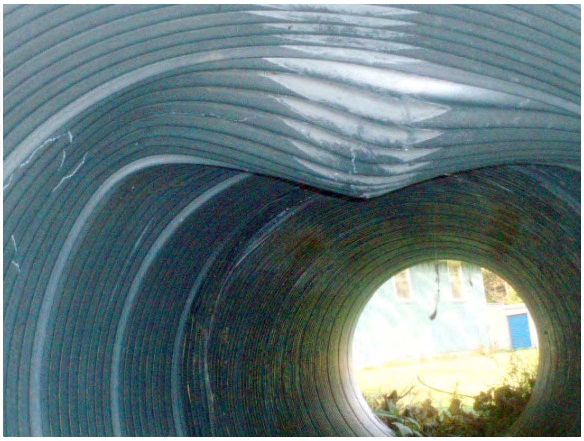
Rt. 61 SBL, Co. Rd. 464, Side Rd. Pipe, Lewis Co. - New 36” riveted GSP –with end crushed in near outlet and hole near inlet end with daylight showing thru.


Rt. 61 SBL, Co. Rd. 464, Side Rd. Pipe, 36”d. riveted GSP – 6”diam. hole 2 ft. in from inlet, rocks poking thru.

There were some potential problems found with the newer helically wound metal pipe. The helically running seam and the helical corrugations make the pipe easier to deform when placing in a trench as done in maintenance pipe replacements and when backfilling the pipe. The crimped joint running through the pipe could be forced opened if pressure from improper backfill is placed over them. Some of the seams are shown below that are being strained at bulges caused by improper backfilling but they seem to be holding together so far.

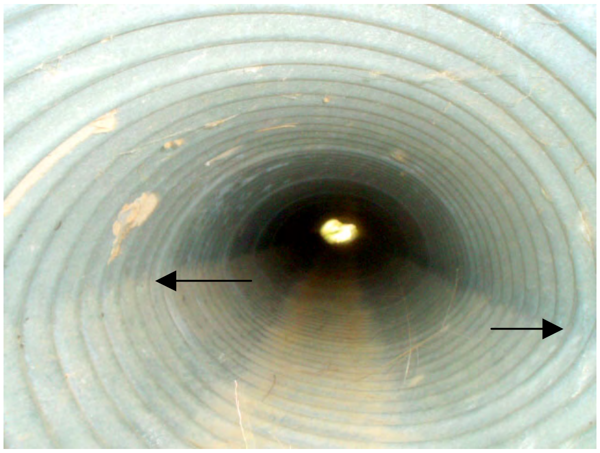
Christian Co., Rt. 125, 8.0 S Co. Ln., 2-48"d. GSP, helical pipe. - Crushed but not torn 4 places.





Christian Co., Rt. 125, 8.0 S Co. Ln., 2-48"d. GSP, helical, - crushed on top, 11" deflection.
- crushed on top near seam, seam holding.

Rt.71, McDonald Co., Sta. 637+09 Lt. -, 36" Group B –
worst dent deflected in 5" at top on seam, and looking from other end - dented two other places at top.



Dallas Co., Rt. F, 18”d. GSP – deflected dimensions are 18” high x 23” wide, inside is bending at different elevations on each side. Assume it is really a 20”d. pipe; Cause - not enough overfill height, vehicle loads transferring straight to pipe.

There were also problems with connecting sections at the joints, especially in larger diameters of pipe. The helical corrugations at section ends have to be crimped and circumferential corrugations put on the ends to receive the coupling bands. The corrugations are sometimes half as deep as the helical corrugations on the rest of the pipe and do not have as much mechanical bond with the coupling bands. This problem was noticed on a 72”d. pipe on Rt. 50, Cole County but the connections on Rt. 160, Greene County project using channeled helical construction rather than corrugations seem to make a better connection when the ends are corrugated for the joint couplings. Examples of both connections of helical pipe are shown below.

Rt. 50 Cole Co., 72” Helical corrugated pipe – crimped down and re-corrugated approximately 1” deep (close up on rt.). Looks good, has been painted with zinc paint, but the shallow corrugations don’t provide much mechanical grab for the connecting bands on the outside of this 6 ft. diameter pipe.

Job J8U0535, Rt. 160, Greene Co., 48” Group B, W. side 0.1 N.of Wadill St. – pipe is helical channel construction, corrugated ends make cleaner joint.

There were other problems like mower damage of pipe ends and flared end sections when they don’t match the roadway in-slopes well. There are two inspection photos illustrating these problems shown below; bad and good treatments on different ends of the same pipe.

Lawrence Co. Rt. 37, 0.9 S Newton Co.Ln. 18” CMP – crushed pipe end and steel FES, and good backfill around steel FES, other side of road.

Concrete Pipe Inspection

A total of 75 concrete culvert pipe were inspected. According to records available all of these were steel reinforced concrete pipe except for two installed in 1936 on Franklin County Route 185 that are non-reinforced. There are more non-reinforced pipe out there but there is no record of them. Reinforced Concrete Pipe (RCP) culvert is specified by classes, Class I to V depending on the amount of overfill height or load they can support, Class I being the lightest and Cl. V the strongest. The diameter, wall thickness, compressive strength of the concrete and the quantity of circumferential reinforcement are as prescribed in Tables 1 through 5 of AASHTO M 170. MoDOT specifies mostly Cl. III and higher for cross road pipe on major highways. Concrete pipe is rigid and is constructed of sections. It is made in lengths from approximately 4 ft. long to 10 ft. long depending on size and weight needed to lay it with conventional equipment. The connections are usually a bell and spiggot pushed together with some kind of sealant between sections. These connections or joints are usually the trouble spots for installation and maintenance of the culvert. Inspection guidelines for RCP culvert are based on three categories Cracks and Condition (of the concrete), Joint Condition and Alignment with ratings in each category from low to high of 0-9. The oldest pipe that was surveyed was installed in 1935 on Rt. 125, Chrisian County. The inspection rating for Cracks and Condition was still perfect, rated 9. The rating for the Joint condition was 7 because the joints at the end sctions were separated at the inlet, the gap between the first 4 ft. sections was only 1" at the top of the pipe, but daylight could be seen through it. The end joint at the outlet end was seperated 4" but the joint wasn't open, all of the interior 4 ft. sections the joints were tight. The alignment was rated 8 because of slight deflection (less than ¼" in 10ft. length) at the inlet and outlet sections. This pipe had no joint compound in the joints. New RCP pipe now have asphalt joint compound material or occasionally there will be a special design calling for gasket type joints. Several inspection photos are shown below illustrating these conditions.

Rt. 185, Franklin Co., 24"d. non-reinforced concrete pipe, 1936 – open gap in pipe with stick in it.

Rt. 185, Franklin Co., 24"d. non-reinforced concrete pipe, 1936 – joints deteriorating.

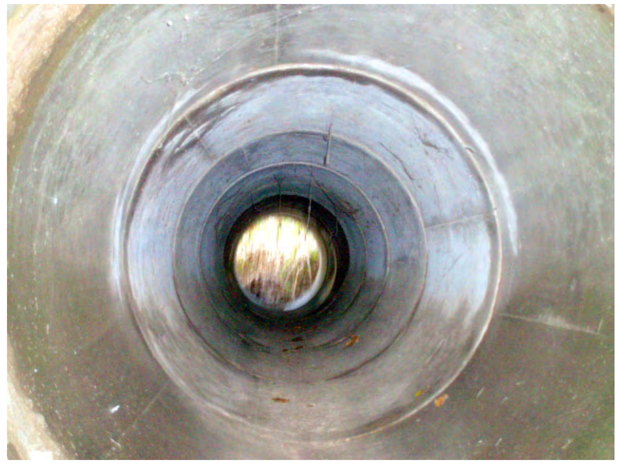

Rt.61, Pike Co., 0.15 Rp.54-61N, 1979, 36"d. RCP- Inlet FES & inlet 1st joint deteriorated 6" rebar rusted off.


Rt.61, Pike Co., 0.15 Rp.54-61N, 1979, 36"d. RCP-outlet FES, chewed up by mowers



Rt. 61, Pike Co., 1996, 0.7 Ralls Co. Ln., 42" Cl. IV& Cl.III RCP – inlet FES & 3" gap at joint between FES and 1st section pipe.


Rt. 61, Pike Co., 1996, 0.7 Ralls Co. Ln., 42" Cl. IV& Cl.III RCP – 4" gap @ outlet FES



Rt. 125, Christian Co., 1.2 S Greene Co Ln, 1935, 36” RCP – 1935 installation, joints rated 7 condition because 1” gap and open joint at inlet section. 4” gap at joint but not open at outlet end, all interior joints of 4’ sections tight.

Pipe Inspection Ratings

As mentioned earlier, after the 2000 culvert report a survey sheet with ratings similar to those used for the National Bridge Inspection Standards (NBIS) was set up for culvert pipe. Three ratings scales were set up for both CMP and RCP pipe.

- For CMP the three categories are <u>Durability</u>, <u>Joint and Seam Condition</u>, and <u>Alignment</u>.
- For RCP they are <u>Cracks and Condition</u>, <u>Joints Condition</u>, and <u>Alignment</u>.

Ratings are numerical and go from 0 to 9. Each rating has several criteria for the inspector to compare to the pipe being rated. The inspection sheets for both types of pipe have a description of the pipe on the front of the page and ratings on the back page. Examples of the inspection sheets are included in the Appendix 5 for reference.

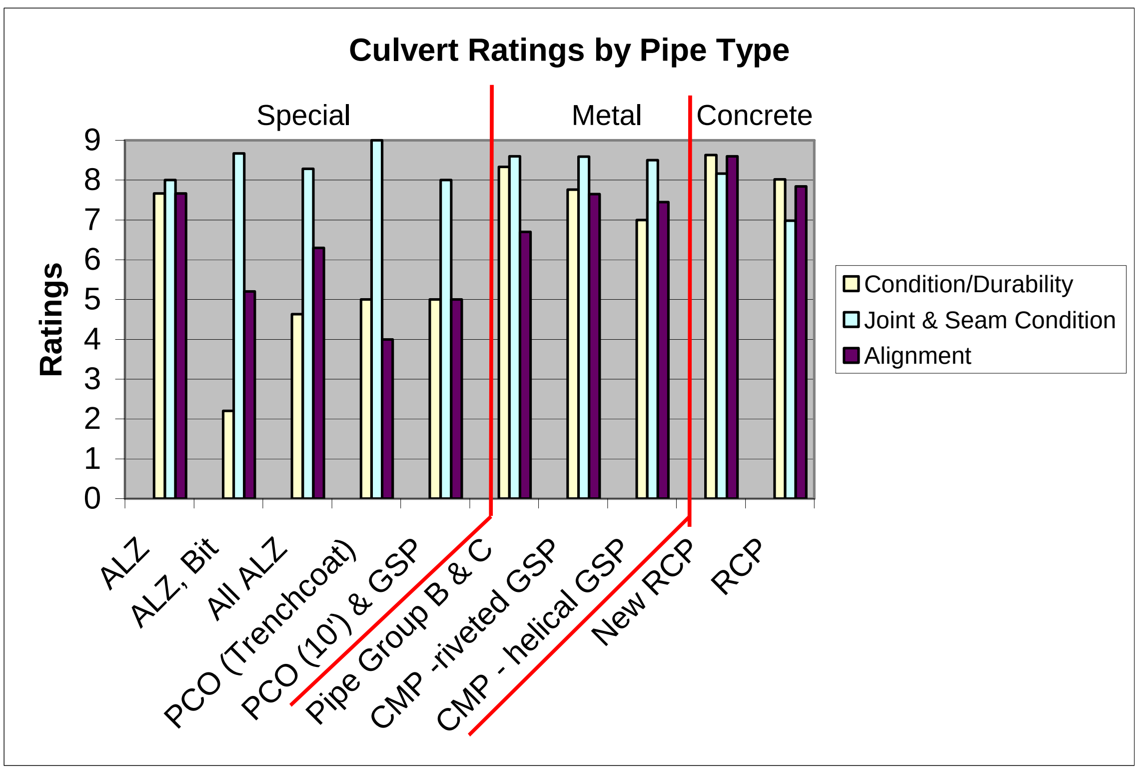
A table with the ratings of all the pipe inspected is presented in Appendix 4. This table was used to produce Table 2 - the average ratings table for the different pipe material types, which was used to produce the two charts presented below.

Table 2: Pipe Ratings by Pipe Type

Description	Cracks & Condition/ Durability	Joint/Joint & Seam Conditiion	Alignment	Pipe Avg
ALU – Aluminum Alloy	7.67	9.00	7.33	8.00
ALZ - Aluminized	7.67	8.00	7.67	7.78
ALZ, Bit – Bitumen coated aluminized	2.20	8.67	5.20	5.36
All ALZ - two categories ALZ combined	4.63	8.29	6.30	6.40
PCO (Trenchcoat) – Polymenr Coated	5.00	9.00	4.00	6.00
PCO (10') & GSP – 10' PCO, rest GSP	5.00	8.00	5.00	6.00
Pipe Group B & C (2004 spec.)	8.33	8.60	6.70	7.88
CMP -riveted GSP	7.76	8.59	7.65	8.00
CMP - helical GSP	7.00	8.50	7.44	7.65
New RCP (2004 spec. Grp. A)	8.63	8.17	8.60	8.47
RCP	8.02	6.98	7.84	7.61

The first chart, Figure 1, shows the average for each of the three rating scales (Condition/Durability, Joint and Seam Condition, and Alignment) of all the pipe of that material type. The second chart, Figure 2, is the overall rating average for each category of pipe.

Figure 1:

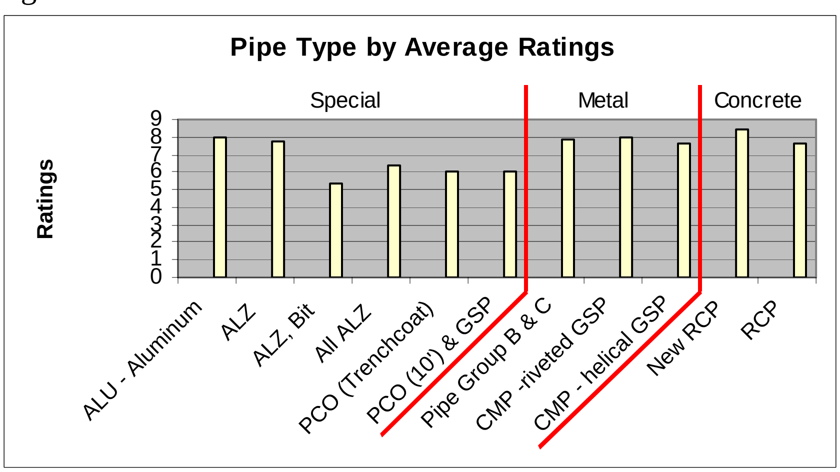


Special metallic pipe are listed first. Aluminum Alloy pipes rate among the best of metallic pipe and it should be noted they are in the 33-45 years age group. Only three of these pipe were

inspected in this study and there is only a half dozen state wide because of the cost of solid aluminum alloy. Aluminized steel pipe was broken into two categories because the old bitumen coated aluminized pipes were in much worse condition than the uncoated aluminized which were rated high in all three criteria and overall with a 7.78 rating, next highest to Aluminum Alloy of the old in-place metal pipe. The bituminous coating was used in District 7 in known acidic areas, instead of just wearing off it must have trapped moisture and acid under it and caused a faster rate of corrosion. The next special material pipe is the polymer-coated steel, PCO. The first listed, located again in St. Clair County in District 7, is the only PCO entirely coated with Trenchcoat, a 3M coating used in 1997, when it was installed. This full-length polymer coated pipe was deteriorating at the outlet end where acid water runoff from this harsh area sat and damaged the pipe, thus it had a condition rating of 5. Another PCO pipe was installed in District 3 in 1990 but only experimentally using a10 ft. section of the PCO pipe attached to a longer section of galvanized steel. The PCO part of this pipe, which was the inlet section, was rated 8, however, the galvanized steel CMP portion of the pipe had a condition rating of 5 because the invert was mostly covered with rust, this brought the overall rating to 6. These PCO pipe also have a problem of the outside coating deteriorating from ultra-violet light and the coating peeling off.

New galvanized steel CMP pipe are next and are listed as Group B & C pipe per the 2004 specifications. Even though these are new pipe installed after 2001 and have ratings above 8 for Durability and Joint and Seam Condition, they are rated below 7 on Alignment. These pipes are more flexible than concrete and need extra care taken when preparing the subgrade and backfilling, much like polyethylene (HDPE) pipe discussed in a previous report, Organizational Results Research Report OR08-002. The general CMP pipe, which are all galvanized steel pipe, are broken down into the older riveted corrugated plate sections and the newer helically wound corrugated types. The 18 CMP riveted were installed between 1993 to 2007 and had an overall rating of 8.0 slightly higher than the nine helical CMP installed between 1995 to 2002 with an overall inspection rating of 7.65. The ratings for Alignment were slightly less for the helical pipe. It was shown earlier that this pipe is flexible and can be damaged and punctured by rocks and the alignment changed if not backfilled properly.

Figure 2:



That leaves only reinforced concrete pipe left (RCP), Group A in the 2004 specifications. The Condition and Alignment ratings are very high on these, over 8.5 for the new and near 8.0 for the older RCP pipe. The joints are the main problems and that rating was a little lower, 8.17 for the new and 6.98 for the older pipe. The overall rating for the 30 New RCP pipe installed 2002-2007 was 8.47 and for the 45 old RCP installed 1935-2001 was 7.61. Overall the Condition and Alignment ratings for concrete are better than metal but the Joint rating is more than one point less than metal pipe. It should be noted that the concrete pipe inspected in this study have been in service for as long as 72 years. Compare this to metal pipe inspected that have been in service only 5 to 14 years and one just installed in November 2007. If aluminized steel pipe are included in the metal category the oldest inspected was installed in 1952 and has been in service 55 years.

Conclusions

Field investigation of metal and concrete pipe culverts in the state of Missouri since 1991 have shown that reinforced concrete pipe (RCP) is the most durable and long lasting pipe and this study indicates the same conclusion. Although the 125 culverts that were inspected don't constitute enough data to the tens of thousands of culvert pipe installed on the state roads, it has been shown again, by the available information, that concrete pipe could last 100 years. The inspection ratings done during the last two inspections proved to be very valuable at coming to some general conclusions. After reinforced concrete pipe the highest rated and longest lasting pipe were the Aluminized or Corrugated Aluminum-Coated Steel Culvert Pipe. (Note: Of the in-place pipe; Aluminum Alloy CMP were actually rated higher than RCP, but there are so few and structurally they may not meet specifications for cross road pipe so they were left out.)

The corrugated metal pipe seems to be lasting somewhat longer when built of riveted plates rather than helical wound pipe. There are two possible areas of concern noticed during this study with the helical construction. First, the crimped joint running through the pipe could open if pressure from improper backfill is placed over them. Second, there are potential problems with connections at the joints, especially in larger diameters, which can come apart. Because the helically formed ends of the sections need to be crimped and new circumferential corrugations put on them to receive the coupling bands used to join them. There seems to just not be enough depth and mechanical locking at these joints to hold under large loads. The older installed CMP and some of the just newly installed on construction projects, whether riveted or helical construction, show some large deflections in alignment and bulges and punctures by rocks. These deformations resulted from backfilling procedures not meeting the standard specifications.

Recommendations:

The data suggests that as far as the classification of pipe by the new 2004 Specifications, Section 726 for Rigid Pipe Culverts, that Reinforced Concrete Culvert Pipe should remain in Group A. RCP has shown a life of 70 plus years installed and could last the 100-year design life with no problems. All of the corrugated metal pipe should remain in Group B or Group C. Culvert data gathered over the years has determined that, on average steel pipe will last 40 years, the

bituminous/aluminum coated pipe in this inspection have lasted 47 years. The limited data from this study suggests that Aluminum Alloy pipe and Aluminum Coated Steel pipe could prove with further experience that they could move up into Group A. It seems that if CMP is to move up to Group A, a new look at specifying wall thickness needs to be studied since such large deformations and damage was noted in this study even on newer installations.

The biggest problem with metallic pipe is corrosion. This is especially true in areas with acidic soils or runoff and sulfates such as the area in Southwest Missouri that has been mapped out showing the Pennsylvania strata. It is recommended that only concrete and HDPE pipe be used in this area with the exception of possibly allowing Aluminum Alloy pipe. It has been shown that zinc coating and any other coatings on corrugated steel pipe used in the past have not been satisfactory to withstand the harsh acidic environment. There is a need to do a soil survey when installing culvert pipe in corrosion prone areas in Southwest Missouri. It is also essential to assure homogeneous soil is used for backfill at every location that a metal pipe is being installed, this will help delay some of the corrosion problems.

Preparation of the pipe bedding and proper backfilling of pipe continues to be a problem that shows up in these surveys. It is important in new installations of RCP to make sure that joints are held together and stay together during the life of the pipe. CMP inspected showed some problems in keeping good alignment and several problems with improper backfill deflecting denting and puncturing this less rigid pipe. Care needs to be taken to follow standard specifications in constructing new pipe and best practices in installing new replacement pipes by maintenance forces.

Inspection ratings were very helpful in analyzing the pipes performance but only ratings for pipe inspected since 2001 were used. It would be beneficial if this study could be expanded to ensure enough pipes of different diameter size groups, different age groups, and located in different geological areas could be used to make sure the number is more statistically significant. The analysis proposed in the 2000 Culvert Study Report would probably take a minimum of six months to complete. This would take a large expenditure of time and personnel that may not be justified at this time.

Appendix 1

Table 2 - Itemized Number of Pipes Inspected as Listed in 2000 Study

Survey Date	2000	2007
Aluminized	25	1
Aluminum	5	5
Polymer Coated	4	2
Galvanized	1	0
Reinforced Concrete	82	20
Total	**117**	**28**

Table 3 – Pipe Re-Inspected from 2001-2003 Study based on Geographic Areas

DISTRICT	D-1	D-3	D-5	D-7	D8	D10	Total
Corrugated Metal Pipe	3	2	3	9	1	3	21
Reinforced Concrete	6			5			11
Total	**9**	**2**	**3**	**14**	**1**	**3**	**32**

Table 4 – New (First Time) Pipe Inspections in 2007

DISTRICT	D-1	D-3	D-4	D-5	D-6	D-7	D-8	Total
Corrugated Metal Pipe	4				2	2	1	9
Reinforced Concrete	3	3	10	2		9	4	31
Total	**7**	**3**	**10**	**2**	**2**	**11**	**5**	**40**

Table 5 – Newly Installed Culverts on Construction Projects built from 2001-2006

DISTRICT	D-1	D-3	D-5	D-7	D8	D9	D10	Total
Corrugated Metal Pipe	1	1	3	1	3	3		12
Reinforced Concrete	1	3	7		1		1	13
Total	**32**	**4**	**10**	**1**	**4**	**3**	**1**	**26**

Total Number of Culvert Pipe Inspected

Metal	**RCP**	**TOTAL**	
8	20	28	2000 Survey List
21	11	32	2001-2003 Study based on Geographic Areas
9	31	40	2007 First-Time Inspection
12	13	25	2001-2006 New Installed Culverts (Construction Projects)
50	**75**	**125**	

Appendix 2 - Complete List of Metallic and Concrete Culvert Pipe Inspected 2007

Restrictions:

Diameter: 30 in — CMP = Corrugated Metallic Pipe

Diameter: 80 ft — RCP = Reinforced Concrete Pipe

Description	Year	Diameter (in)	Length (ft)	Route	Contract #	District	Location	Count
District 1								
Class III RCP	**2002 - 2003**	**30**	**155**	**136**	**011116-101**	**1**	**Albany**	1
Class III RCP	**2002 - 2003**	**48**	**119**	**136**	**011116-101**	**1**	**Albany**	2
Class III RCP	**2002 - 2003**	**54**	**180**	**59**	**020315-111**	**1**	**Oregon**	3
Pipe Culvert Group B	**2002 - 2003**	**30**	**100**	**136**	**011116-101**	**1**	**Albany**	4
Pipe Culvert Group B	**2002 - 2003**	**36**	**116**	**59**	**020315-111**	**1**		5
Pipe Culvert Group B	**2002 - 2003**	**42**	**80**	**59**	**020315-111**	**1**		6
Pipe Culvert Group B	**2003 - 2004**	**30**	**106**	**136**	**011116-101**	**1**	**Albany**	7
RCP	1950	18	35	111		1	Atchison-1.5 N RT.W Holt Co. RT X from 18" RCP	8
RCP	1950	12		111		1	Atchison-1.5 N RT W Holt Co.Lt, Kettle Rd W. Ent.	9
RCP	1950	18		111		1	Atchison - 2.1 N RT. W Holt Co., 315th St. E end	10
RCP	1952	30	110	6		1	Daviess - 24.0 E. Dekalb Co.	11
RCP	01-Jan-42	30	44	B		1	Daviess - 14.86 W. of Rt. I-35 4 sections	12
RCP	1947	24	48	M		1	Daviess - 1.35 W. of Rt.13*-00 Culvert Report	13
RCP	1961	36	45	33		1	Dekalb - 0.71 S.Rt. 6** Soil Type Inspection Book	14
RCP	1961	24	75	33		1	Dekalb - 1.4 S.Rt. 6**	15
RCP	1961/1981	30/24	83	33		1	Dekalb - 2.25 S.Rt. 6**,24"x16' Added @ inlet 1981	16
CMP - GSP	1998	48	50	D		1	Dekalb - 0.3 SS. Rt. E**	17
RCP	1967	18	64	136		1	Harrison - 1.6 Gentry Co.*	18
RCP	01-Jan-54	36	88	136		1	Harrison -LM 10.31, 4 sections	19
CMP	11/6/2007	54		M		1	Harrison - 3.0 W Rt.69	20
CMP	2001	18	18	111		1	Holt - 0.7 N Rt.159, Paved driveway in Big Lake	21
ALZ	10/7/1993	15	56	111		1	Holt - LM4.7 Lt., 3.4 S Rt.W	22
CMP - GSP	2001	15	43	111		1	Holt - 1.05 N Rt.59, @ # 398 Rt. 111	23
ALZ - helical	10/14/1993	16	43	111		1	Holt - LM 5.537, 4.2 S Rt. W	24
RCP	1950	18	24	111		1	Holt - .74 N.Rt.W, Ent. Pipe	25
ALZ	01-Jan-52	36	56	246		1	Nodaway - 3.24 E 148	26
District 3								
Class III RCP	**2006 - 2007**	**66**	**216**	**61**	**050624-302**	**3**	**Canton**	1
Class III RCP (Gasket type)	**2006 - 2007**	**42**	**181**	**61**	**050624-302**	**3**	**Canton**	2
Pipe Culvert Group C	**2006 - 2007**	**36**	**90**	**61**	**050624-302**	**3**	**Canton**	3
GSP	1997	15	48	168		3	Marion - 7.0 from Co.Ln., Entrance Rt.	4

Description	Year	Diameter (in)	Length (ft)	Route	Contract #	District	Location	Count
GSP	1997	15	55	168		3	Marion - 7.2 from Co.Ln., Just W.of Rt.O	5
PCO (10') & GSP	10/4/1990	48	10/*	V		3	Monroe - 3.2 S Shelby Co. Line	6
ALU - Aluminum	1974	30	35	161		3	Montgomery-3.1 S RT CC,10' PCO rest Helic.GSP	7
RCP	1996	36	86	61		3	Pike - 0.15 Rp 2, Ramp 54-61N	8
Class III & Class IV RCP	1996	42	105	61		3	Pike - 0.69 from Ralls Co.Ln.	9
Class IV RCP	1978	36	414	61		3	Pike - 13.95 from Ralls Co.Ln.	10
District 4								
Class III RCP	**2002 - 2003**	**750**	**75.5**	**13**	**010720-401**	**4**	**Lexington**	1
Class III RCP	**2002 - 2003**	**900**	**71.5**	**13**	**010720-401**	**4**	**Lexington**	2
Class III RCP	**2002 - 2003**	**900**	**32**	**13**	**010720-401**	**4**	**Lexington**	3
Class III RCP	**2002 - 2003**	**900**	**32**	**13**	**010720-401**	**4**	**Lexington**	4
Class III RCP	**2002 - 2003**	**1200**	**32.5**	**13**	**010720-401**	**4**	**Lexington**	5
Class III RCP	**2002 - 2003**	**1200**	**32.5**	**13**	**010720-401**	**4**	**Lexington**	6
Class III RCP	**2002 - 2003**	**1500**	**81**	**13**	**010720-401**	**4**	**Lexington**	7
Class III RCP	**2002 - 2003**	**1500**	**81**	**13**	**010720-401**	**4**	**Lexington**	8
Class III RCP	**2002 - 2003**	**1500**	**81**	**13**	**010720-401**	**4**	**Lexington**	9
Class IV RCP	**2002 - 2003**	**1500**	**116**	**13**	**010720-401**	**4**	**Lexington**	10
District 5								
Class IV RCP	**2003 - 2004**	**36**	**111**	**54**	**021213-503**	**5**	**Lake Ozark**	1
Class V RCP	**2003 - 2004**	**36**	**97**	**54**	**021213-503**	**5**	**Lake Ozark**	2
RCP	1960	18		54		5	Camden - LM 19.46,@ Panorama Ave. in Camdenton	3
RCP	1977	30	213	50-63		5	Cole - 1.26 W Jct. J & M	4
RCP	1977	30	331	50-63		5	Cole - 0.5 W Jct. J & M	5
RCP	1999	36	213	179		5	Cole - 0.3 N.of W. Edgewood	6
RCP	1979	42	170	63		5	Maries - 16.0 S Osage Co.Ln.	7
RCP	1979	30	111	63		5	Maries - 17.34 S Osage Co.Ln.	8
RCP	1979	36	124	63		5	Maries - 15.6 S Osage Co.Ln.	9
CMP	1997	36		H		5	Cole - 3.455 S Rt.54	10
CMP	1997	18		H		5	Cole - 3.8 S Rt.54	11
CMP	1997	18		H		5	Cole - 4.0 S Rt.54	12
CMP	1994	24	40	U		5	Cole - 0.2 N Rt.C	13
CMP	1994	30		52		5	Miller 1.2 E Rt. 17- Entrance Rt.	14
CMP	1994	36		52		5	Miller 1.3 E Rt. 17- Entrance Lt.	15
CMP	1994	36		52		5	Miller 1.5 E Rt. 17- Entrance Lt.	16
District 6								
Pipe Culvert Group C	**2005 - 2006**	**42**	**78**	**T**	**050218-606**	**6**	**Rt. - Sta 13+46 to 14+56**	1

Description	Year	Diameter (in)	Length (ft)	Route	Contract #	District	Location	Count
Pipe Culvert Group C	**2005 - 2006**	**42**	**79**	**T**	**050218-606**	**6**	**Rt. - Sta 13+46 to 14+56**	2
RCP	1962	30		47		6	Franklin - 2.85 Warren Co.,2.1 S Rt.100	3
RCP	1947	18		47		6	Franklin - 12.23 Warren Co.	4
RCP (non-reinforced)	1936	18		185		6	Franklin - 16.8 Rt. 100	5
RCP (non-reinforced)	1936	24	40	185		6	Franklin - 22.95 Rt. 100	6
District 7								
Class III RCP	**2003 - 2004**	**54**	**182**	**71**	**030321-701**	**7**	**Pineville - Sta. 750+79 (0.35 N Rt.OO), 2 elbows**	1
Class III RCP	**2003 - 2004**	**54**	**176**	**71**	**030321-701**	**7**	**Pineville - Sta. 0+73**	2
Class III RCP	**2004 - 2005**	**42**	**99**	**71**	**030321-701**	**7**	**Pineville - Sta. 10+51 SR Conn. @ Sta. 633+69 Rt.71**	3
Class III RCP	**2005 - 2006**	**42**	**200**	**71**	**050422-701**	**7**	**Sta. 10+77 Rp. 2**	4
Class III RCP	**2005 - 2006**	**42**	**166**	**71**	**050422-701**	**7**	**Goodin Hollow Co.Rd. - Sta. 57+88**	5
Special RCP+(72"Cl.IV')	**2005 - 2006**	**60**	**699**	**71**	**050422-701**	**7**	**McDonald Co. last 32' @ outlet 72" incl. Baffle Rings**	6
Class III RCP (Gasket Type)	**2005 - 2006**	**36**	**413**	**71**	**050422-701**	**7**	**SBL, Sta. 709+63 (Energy dissipator & 3'deep wier)**	7
Class IV RCP	**2003 - 2004**	**54**	**129**	**71**	**030321-701**	**7**	**Pineville - Sta. 7+36 SR Rt.**	8
Class IV RCP	**2005 - 2006**	**36**	**405**	**71**	**050422-701**	**7**	**Sta. 11+81 Rp.1 (@ new Rt.H)**	9
Pipe Culvert Group B	**2004 - 2005**	**36**	**104**	**71**	**030321-701**	**7**	**Pineville - Sta. 540+00 Lt.**	10
Pipe Culvert Group B	**2004 - 2005**	**36**	**80**	**71**	**030321-701**	**7**	**Pineville - Sta. 637+08 Lt. (helical)**	11
RCP	1965	30	90	37		7	Barry - 1.04 Rt. 60	12
RCP	1958/1997	36	56/88	60		7	Barry - 1.53 E Rt. 37, Extended 16' each end + FES	13
RCP	1942	24	54	W		7	Barry - 6.553 Rt. 86	14
RCP	1938/1971	24	50	K		7	Barton 4.379 KS State Line, Ext. 4' each side	15
ALZ, Bit	1959	36	31	K		7	Barton - 0.2 E KS State Line	16
ALZ, Bit	1960	54	35	P		7	Barton -2.6 S Rt. K	17
ALU	1962	24	20	NN		7	Barton - Rt. Side 0.5 S Rt.K	18
ALZ, Bit	1960	36	38	P		7	Barton - 4.2 S Rt.K	19
ALZ, Bit (Pipe Arch)	1960	32 x 45	33	P		7	Barton - Rt. Side 1.4 S Rt.K	20
RCP	1994	18	36	B		7	Bates - 1.0 E Rt. 71	21
RCP	1995	24	48	B		7	Bates - 0.4 E Rt.71	22
RCP	1968	30	57	32		7	Cedar - 0.61 S. Rt. 54	23
RCP	1956	48	71	171		7	Jasper - 1.388 S Rt. 43	24
CMP (GSP-Helical)	2000	16	30	D		7	Jasper - 2.6 S Rt. 96	25
CMP (GSP-Helical)	2002	18	36	37		7	Lawrence - 0.5 S Newton Co Ln	26
CMP (GSP)	2002	18	36	37		7	Lawrence - 0.76 S Newton Co Ln	27
CMP (GSP)	2002	18	36	37		7	Lawrence - 0.88 S Newton Co Ln	28
RCP	1950	30	40	90		7	McDonald - 2.395 Rt. 59	29
RCP	1957	24	204	43		7	Newton - 0.27 S Jasper Co.	30

Description	Year	Diameter (in)	Length (ft)	Route	Contract #	District	Location	
RCP	1957	30	130	43		7	Newton - 0.22 S Jasper Co.	31
RCP	1962	24	64	43		7	Newton - 2.543 Jct. Rt. C	32
RCP	1940	24	90	59 (0ld 71)		7	Newton - 0.169 McDonald Co.	33
RCP	2001	30	90	NN		7	Newton - .01 E Rt. 86	34
RCP	1954	24	41	O		7	Newton - 2.476 Rt. 86	35
RCP	1977	18	61	82		7	St. Clair - 0.12 W Hickory Co Ln	36
PCO-Trenchcoat	1997	60		B		7	St. Clair - 4.5 W Rt.13	37
ALU - Aluminum	1962	15	30	F		7	Vernon - 2.5 W RT 43	38
ALZ, Bit (Pipe Arch)	1958	36x42	30	KK		7	Vernon - 1.2 W Rt.43	**39**
RCP	1970	24	81	43		7	Vernon - 3.25 S Rt. 54	40
District 8								
Class III RCP	**2001 - 2002**	**48**	**489**	**64**	**010518-802**	**8**	**Lebanon-Rt.5 Intersect, Sta.576+73 to 581+52 Lt.**	1
Group B - RCP	**2006 - 2007**	**30**	**153**	**160**	**051118-801**	**8**	**Springfield - 0.23 N Commercial St.**	2
Pipe Culvert Group B	**2006 - 2007**	**48**	**532**	**160**	**051118-801**	**8**	**Spfld.- 0.1 N Wadill St. Lt., goes to holding pond**	3
Class III RCP	**2006 - 2007**	**42**	**79**	**160**	**051118-801**	**8**	**Spfld.- Sta.47+49, 0.1 S Division St.**	4
Class III RCP	**2006 - 2007**	**48**	**76**	**160**	**051118-801**	**8**	**Spfld.- Sta. 13+64, 0.1 N Wadill St.**	5
RCP	1935	36		125		8	Christian - 1.23 S Greene Co Ln	6
CMP	1994	2@48*		125		8	Christian - 8.0 S Greene Co Ln	7, 8
CMP - helical GSP	1998	20		F		8	Dallas - 0.98 S Rt.65	9
CMP - helical GSP	1998	30		F		8	Dallas - 1.25 S Rt. 65	10
CMP - riveted GSP	1998	18	20	F		8	Dallas - 1.98 S Rt. 65, SR pipe Rt.	11
District 9								
CMP	1994	18	40	119		9	Dent - 0.15 S Rt. 32	1
CMP - helical	1995	36	40	119		9	Dent - 0.5 S Rt. 32	2
CMP - riveted	1993	36	40	119		9	Dent - 1.2 S Rt. 32 @ Road 604	3
District 10								
RCP	1940	24	100	61		10	Ste. Genevieve - 0.1 N Perry Co Ln	1
CMP - helical GSP	2001	14		EE		10	Ste. Genevieve - 2.75 S Rt. C, S Entrance	2
CMP - helical GSP	1997	18		EE		10	Ste. Genevieve - 2.6 S Rt. C	3
CMP - helical GSP	1997	18		EE		10	Ste. Genevieve - 0.9 S Rt. C	4

*Double pipe at Rt.125, Christian Co. counted as 2 pipe

TOTAL Inspected 2007 126*

Appendix 3 - pH Readings from 2000 and 2007

					Soil PH					Water PH				
County	Route	Location	Type	Install date	94	95	96	98	2007	94	95	96	98	2002
Dist 1														
Davi	E	2.85 E DEKA CO LN	DWP	04/16/92	7.3	7.5	7.1	7.1						
Daviess	6	0.1 E Rt. NN	30" RCP	01/01/52										7.5
Daviess	6	14.9 E I-35	30" RCP	12/18/41					7.3					
Daviess	M	1.35 E Rt. 13	24" RCP	01/01/47					8.1					
Deka	D	1.55 N RT 6	DWP	04/14/92	7.2	6.7	6.6	6.8						
Deka	D	2.1 N RT 6	DWP	04/13/92	7.1	6.8	6.9	7.1						
Deka	D	3.75 N RT 6	DWP	04/13/92	6.6	7.0	7.1	6.7			7.3	6.7		
Deka	D	0.3 S Rt. E	48" GSP	01/01/98										7.9
Deka	33	1.4 S Rt. 6	24" RCP	01/01/66										7.5
Deka	33	0.7 S Rt. 6	36" RCP	01/01/61					8.1					
Deka	33	2.3 S Rt. 6	24"/36" RCP	01/01/61					8.1					
Gentry	136	2.0 E Rt.N/Sta.175+00	48" Cl.III RCP	01/01/01										7.4
Gentry	136	Co. Rd. 540 Rt.	30"Gp.B GSP	01/01/01					7.6					7.9
Harrison	136	10.2 E Gentry Co Ln	36" RCP	01/01/67										7.0
Harrison	136	1.6 E Co. Ln.	18" RCP	01/01/67										7.5
Harrison	136	1.6 E Co. Ln.	18" RCP	01/01/67										7.3
Holt	111	4.1 N RT 111 S	ALZ	10/14/93	6.7	7.4	7.1	7.0						
Holt	111	4.9 N RT 111 S	ALZ	10/07/93	6.9	7.8	7.1	7.1						
Holt	111	5.5 S Atch Co Ln	16" ALZ	10/14/93					7.3					
Holt	111	0.7 N Rt. 159	18" GSP	1/1/2001					7.7					
Holt	59	Sta1560+08 Lt.	42"GpB GSP	01/01/02					7.7					
Holt	59	Sta. 159+27	54" CIIII RCP	01/01/02										7.6
Holt	119	0.75 N Rt.W	18" RCP	01/01/50					7.9					
Noda	246	3.24 E RT 148	ALZ	01/01/52	6.8	7.0	7.3	6.9		7.3	6.9	7.0	6.7	
Nodaway	246	3.3 E Rt. 148	36" ALZ	07/30/52										7.9
Dist 3														
Lewi	81	1.9 N RT 16	DWP	10/12/93	6.9	7	6.9	6.6		7		6.3		
Lewis	61	Co. Rd. 461	42"Cl.III RCP	1/1/2007										6.9
Lewis	61 SBL	Sta169+43	36"Gp.C GSP	1/1/2007					7.9					
Mari	A	0.8 N RT 168	DWP	01/01/94	5.6	7	6.6	6.8					6.7	
Mari	C	0.15 S RT 168	DWP	01/01/94	6.8	7.2	6.6	7.1						
Mari	P	3.3 N RT A	CPE	01/01/94	6.8	6.8	6.9	7.1		7.1	6.5		6.8	
Marion	168	7.2 from Co Ln	15" GSP	01/01/97					7.4					7.6
Monr	V	2.45 S SHEL CO LN	DWP	04/06/92	6.8	7.3	6.2	6.9						
Monr	V	2.8 S SHEL CO LN	DWP	04/06/92	8.1	7.4	7.2	7.4						
Monr	V	3.0 S SHEL CO LN	DWP	04/06/92	7.1	6.9	7.2	7.6						
Monr	V	3.2 S SHEL CO LN	PCO	10/04/90	7.2	7.1	6.8	7.3			7.1	6.6		
Monroe	V	3.2 S Shelbt Co Ln	48" PCO	10/4/1990										8.1
Mont	161	3.1 S RT CC	ALU	01/01/74	6.9	7.2	6.9	7.2			7.1	6.6	6.9	
Mont	CC	0.7 E RT 161	DWP	05/24/94	7.6	7	6.7	7.4		6.7	7.1	6.7	7.7	
Mont	P	0.7 S RT K	PLI	12/15/91	5.2	5.8	6.9	6.4						
Montg	161	3.1 AS Rt. CC	30" ALU	01/01/74					7.3					7.4
Dist 4														
Lafa	FF	1.07 W RT 13	ALZ	01/01/52	6.6	6.7	6.5	6.6				7.0	5.5	
Lafa	FF	1.46 W RT 13	ALZ	01/01/52		7.0	6.5	7.0					6.7	
Lafa	FF	1.5 W RT 13	ALZ	01/01/52		6.8	6.5					6.6		
Ray	13	Sta. 39+945	1500mm RCP	1/1/2002										8.2
Ray	13	Sta. 36+136	750mm RCP	1/1/2002					7.9					
Dist. 5														
Maries	N	2.9 N RT 28	PLI	08/23/89	6.9			6.8		7.0				
Maries	N	3.0 N RT 28	PLI	08/23/89	6.5			6.8						
Maries	63	16.0 S Osage Co Ln	42" RCP	01/01/79										8.6
Dist.7														
St. Clair	B	4.5 W Rt. 13	60" PCO	9/2/1997				5.7					3.5	4.1
Dist.8														
Dallas	F	1.25 S Rt. 65	30" GSP (Hel.)	1/1/1998										7.4
Greene	160	Sta. 47+49	42"Cl.III RCP	1/1/2007					7.2					
Laclede	64	Rt. 5 Int., N. Side	48"Cl.III RCP	1/1/2002										7.4
Dist.9														
Dent	119	0.5 S Rt. 32	36" GSP	1/1/1995					6.8					
Dent	119	0.15 S Rt. 32	18" GSP	1/1/1994					7.0					

Appendix 4

Pipe Culvert Inspection Ratings

Description	Year	Diameter (in)	Length (ft)	Route	Cracks & Condition/ Durability	Joint/Joint & Seam Conditiion	Alignment	Pipe Avg
Pipe Culvert Group B	**2002 - 2003**	**30**	**100**	**136**	**9**	**8**	**5**	
Pipe Culvert Group B	**2002 - 2003**	**36**	**116**	**59**	**9**	**9**	**6**	
Pipe Culvert Group B	**2002 - 2003**	**42**	**80**	**59**	**9**	**9**	**6**	
Pipe Culvert Group B	**2003 - 2004**	**30**	**106**	**136**	**8**	**9**	**7**	
Pipe Culvert Group B	**2004 - 2005**	**36**	**104**	**71**	**8**	**9**	**8**	
Pipe Culvert Group B	**2004 - 2005**	**36**	**80**	**71**	**9**	**8**	**6**	
Pipe Culvert Group B - helical	**2006 - 2007**	**48**	**532**	**160**	**9**	**9**	**8**	
Pipe Culvert Group C	**2006 - 2007**	**36**	**90**	**61**	**7***	**9**	**7**	
Pipe Culvert Group C	**2005 - 2006**	**42**	**78**	**T**	**7**	**8**	**7**	
Pipe Culvert Group C	**2005 - 2006**	**42**	**79**	**T**	**7**	**8**	**7**	
					8.33	**8.60**	**6.70**	**7.88**
ALU	1962	24	20	NN	7	9	7	
ALU - Aluminum	1974	30	35	161	7	9	6	
ALU - Aluminum	1962	15	30	F	9	9	9	
					7.67	9.00	7.33	8.00
ALZ	01-Jan-52	36	56	246	7	8	7	
ALZ - helical	10/7/1993	15	56	111	8	8	8	
ALZ - helical	10/14/1993	16	43	111	8	8	8	
					7.67	8.00	7.67	7.78
ALZ, Bit	1959	36	31	K	4	9	8	
ALZ, Bit	1960	54	35	P	0	8	7	
ALZ, Bit	1960	36	38	P	5	NA	4	
ALZ, Bit (Pipe Arch)	1960	32 x 45	33	P	0	NA	4	
ALZ, Bit (Pipe Arch)	1958	36x42	30	71	2	9	3	
					2.20	8.67	5.20	5.36
All ALZ					4.63	8.29	6.30	6.40
CMP	1994	24	40	U	8	8	8	
CMP	1994	18	40	119	6	7	8	
CMP (N&S)	1994	2x48		125	8/8	9/9	8/2	
CMP (GSP)	2002	18	36	37	9	9	7	
CMP (GSP)	2002	18	36	37	9	7	7	
CMP - GSP	1998	48	50	D	5	9	5	
CMP - GSP	11/6/2007	54		M	9	9	8	
CMP - GSP	2001	18		111	9	9	9	
CMP - GSP	2001	15		111	9	9	8	
CMP - GSP	1997	36		H	7	9	8	
CMP - GSP	1997	18		H	8	9	8	
CMP - GSP	1994	30		52	9	8	7	
CMP - GSP	1994	36		52	7	9	8	
CMP - GSP	1994	36		52	9	8	9	
CMP - riveted	1993	36	40	119	6	9	8	
CMP - riveted GSP	1998	18	20	F	7	9	8	
GSP	1997	15	48	168	8	9	6	
GSP	1997	15	55	168	7	9	8	
					7.76	8.59	7.65	8.00

Description	Year	Diameter (in)	Length (ft)	Route	Cracks & Condition/ Durability	Joint/Joint & Seam Conditiion	Alignment	Pipe Avg
CMP (GSP-Helical)	2000	16	30	D	8	NA	7	
CMP (GSP-Helical)	2002	18	36	37	9	9	8	
CMP - GSP, helical	1997	18		H	8	9	8	
CMP - helical	1995	36	40	119	1	6	8	
CMP - helical GSP	1998	20		F	8	8	5	
CMP - helical GSP	1998	30		F	7	9	8	
CMP - helical GSP	2001	14		EE	8	9	9	
CMP - helical GSP	1997	18		EE	6	9	6	
CMP - helical GSP	1997	18		EE	8	9	8	
					7.00	8.50	7.44	7.65
PCO (Trenchcoat)	1994	60		B	5	9	4	6.00
PCO (10') & GSP	10/4/1990	48	10/*	V	8/5	8/8	8/5	8/6
Class III RCP	**2002 - 2003**	**30**	**155**	**136**	**9**	**8**	**9**	
Class III RCP	**2002 - 2003**	**48**	**119**	**136**	**9**	**9**	**9**	
Class III RCP	**2002 - 2003**	**54**	**180**	**59**	**7**	**9**	**9**	
Class III RCP	**2006 - 2007**	**66**	**216**	**61**	**9**	**8**	**9**	
Class III RCP	**2002 - 2003**	**750**	**75.5**	**13**	**9**	**6**	**9**	
Class III RCP	**2002 - 2003**	**900**	**71.5**	**13**	**9**	**9**	**9**	
Class III RCP	**2002 - 2003**	**900**	**32**	**13**	**9**	**8**	**8**	
Class III RCP	**2002 - 2003**	**900**	**32**	**13**	**9**	**8**	**8**	
Class III RCP	**2002 - 2003**	**1200**	**32.5**	**13**	**9**	**8**	**8**	
Class III RCP	**2002 - 2003**	**1200**	**32.5**	**13**	**9**	**8**	**8**	
Class III RCP	**2002 - 2003**	**1500**	**81**	**13**	**9**	**8**	**9**	
Class III RCP	**2002 - 2003**	**1500**	**81**	**13**	**9**	**8**	**9**	
Class III RCP	**2002 - 2003**	**1500**	**81**	**13**	**9**	**8**	**9**	
Class III RCP	**2003 - 2004**	**54**	**182**	**71**	**7**	**6**	**8**	
Class III RCP	**2003 - 2004**	**54**	**176**	**71**	**9**	**8**	**8**	
Class III RCP	**2004 - 2005**	**42**	**99**	**71**	**7**	**9**	**6**	
Class III RCP	**2005 - 2006**	**42**	**200**	**71**	**9**	**9**	**9**	
Class III RCP	**2005 - 2006**	**42**	**166**	**71**	**9**	**9**	**9**	
Class III RCP	**2001 - 2002**	**48**	**489**	**64**	**7**	**6**	**8**	
Class III RCP	**2006 - 2007**	**42**	**79**	**160**	**9**	**8**	**9**	
Class III RCP	**2006 - 2007**	**48**	**76**	**160**	**9**	**8**	**9**	
Class III RCP (Gasket type)	**2006 - 2007**	**42**	**181**	**61**	**9**	**8**	**9**	
Class III RCP (Gasket Type)	**2005 - 2006**	**36**	**413**	**71**	**9**	**9**	**9**	
Class IV RCP	**2002 - 2003**	**1500**	**116**	**13**	**9**	**8**	**9**	
Class IV RCP	**2003 - 2004**	**36**	**111**	**54**	**9**	**9**	**9**	
Class IV RCP	**2003 - 2004**	**54**	**129**	**71**	**9**	**8**	**8**	
Class IV RCP	**2005 - 2006**	**36**	**405**	**71**	**9**	**9**	**9**	
Class V RCP	**2003 - 2004**	**36**	**97**	**54**	**9**	**9**	**8**	
Special RCP+(72"Cl.IV)	**2005 - 2006**	**60**	**699**	**71**	**6**	**8**	**9**	
Pipe Culvert Group B (RCP)	**2006 - 2007**	**30**	**153**	**160**	**9**	**9**	**9**	
					8.63	**8.17**	**8.60**	**8.47**

Description	Year	Diameter (in)	Length (ft)	Route	Cracks & Condition/ Durability	Joint/Joint & Seam Conditiion	Alignment	Pipe Avg
Class III & Class IV RCP	1996	42	105	61	7	7	8	
Class IV RCP	1978	36	414	61	9	7	8	
RCP	1950	18	35	111	4	9	8	
RCP	1950	12		111	3	3	6	
RCP	1950	18		111	8	6	7	
RCP	1952	30	110	6	8	6	8	
RCP	01-Jan-42	30	44	B	8	4	7	
RCP	1947	24	48	M	8	3	4	
RCP	1961	36	45	33	5	6	8	
RCP	1961	24	75	33	9	8	8	
RCP	1961/1981	30/24	83	33	9	7	6	
RCP	1967	18	64	136	7	8	8	
RCP	01-Jan-54	36	88	136	9	5	8	
RCP	1950	18	24	111	9	4	7	
RCP	1996	36	86	61	6	8	8	
RCP	1960	18		54	9	7	9	
RCP	1977	30	213	50-63	9	8	9	
RCP	1977	30	331	50-63	9	8	9	
RCP	1999	36	213	179	9	8	8	
RCP	1979	42	170	63	4	7	9	
RCP	1979	30	111	63	9	5	9	
RCP	1979	36	124	63	7	8	8	
RCP	1962	30		47	9	8	8	
RCP	1947	18		47	9	8	6	
RCP	1965	30	90	37	9	8	8	
RCP	1958/1997	36	56/88	60	9	9	9	
RCP	1942	24	54	W	8	8	8	
RCP	1938/1971	24	50	K	9	5	7	
RCP	1994	18	36	B	9	7	8	
RCP	1995	24	48	B	9	8	8	
RCP	1968	30	57	32	9	9	8	
RCP	1956	48	71	171	9	8	8	
RCP	1950	30	40	90	8	8	8	
RCP	1957	24	204	43	9	8	8	
RCP	1957	30	130	43	8	8	9	
RCP	1962	24	64	43	9	8	8	
RCP	1940	24	90	59 (0ld 71)	9	8	8	
RCP	2001	30	90	NN	9	7	6	
RCP	1954	24	41	O	8	6	7	
RCP	1977	18	61	82	8	5	8	
RCP	1970	24	81	43	9	8	9	
RCP	1935	36		125	9	6	8	
RCP	1940	24	100	61	9	9	8	
RCP (non-reinforced)	1936	18		185	7	8	9	
RCP (non-reinforced)	1936	24	40	185	5	5	9	
					8.02	6.98	7.84	7.61
							TOTAL Inspected 2007	125

Appendix 5

CMP RATING

District________________
County________________
Route________________
Log Mile from Nearest
Location________________
GPS
Coordinates____________

____
Inspector_______________
Date__________________
Date of Installation______
Type__________________
Test Section____________

FLOW RATE

Light________

Medium______

Heavy_______

ABRASIVE LOAD

7___No abrasive load

6___Silt

5___Silt with sand

4___Sand

3___Sand with gravel

2___Gravel

1___Gravel with rock

0___Rock

Under notes, any item of interest such as soil types are are/not congruent with geographical area, high foliage or buildings blocking pipe from ultraviolet radiation, is culvert near processing, petroleum or other chemical substance not natural to surroundings? Etc.etc.

NOTES:__________________

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(Include surficial material on first initial inspection.)

Crossroad Y N

Re-Test Date______________

Re-Test Date______________

Re-Test Date______________

Re-Test Date______________

DURABILITY

9___New Condition

8___Superficial rust in spots
___Slight Discoloration

7___Moderate rust in spots
____Slight Pitting
____Discoloration
____Loss of base metal in pitted areas approximately 10 %
____Some isolated bulges in barrel

6___Heavy rust
____Pitting
____Some thinning of base metal in isolated areas
____Minor flattening in bottom half and/or minor bulges in top half

5____Invert mostly covered with rust
____Loss of base metal under rust, approximately 10 %
____Severe pitting
____Loss of base metal in pitted areas approximately 30 %
____Bottom half flattened significantly and/or moderate bulges in top half

4___Appreciable rust in majority of pipe
____Inverts covered with rust
____Loss of base metal severe enough that deflection or penetration will occur when struck with hammer
____Significant distortion at isolated locations on top half, extreme flattening

3___Corroded or abraded nearly through
____Extensive heavy rust
____Deep pitting with 60 to 90 % loss of base metal
____Metal may be punctured easily with light blow of hammer
____Distortion throughout pipe, lower third kinked , ponding water

2___Perforation in scattered locations
____Invert with minor perforation not causing significant exfiltration
____Extreme deflection, flattening of crown

1___Perforation extensive in inverts and/or extensive perforation in pipe due to corrosion
____Exfiltration causing erosion of fill material under or around pipe
____Partially collapsed with crown in reverse curve

0___Complete invert rusted out and/or bottom of pipe rusted out
____Failure, collapsed pipe

JOINT AND SEAM CONDITION

9___All joints and seams tight

8___One or more joints loosened less than 1/8 width of band

7___One or more joints loosened 1/8 to ¼ width of band
____Slight faulting at one or more joints due to band loosening
____Slight movement of seams

6___One joint loosened greater than ¼ width of band
____Minor opening of pipe seams
____Minor cracking of welds at seams or around rivets
____Slight infiltration or exfiltration

5___Two or more joints loosened greater than ¼ width of band
____Faulting less than 1" on one or more joints due to band loosening
____Moderate opening of pipe seams
____Moderate cracking of welds at seams or around rivets
____Minor infiltration, exfiltration

4___One joint open exposing one edge of band and backfill material
____Faulting 1 to 2" of one or more joints due to band loosening
____Appreciable opening of pipe seams
____Appreciable cracking of welds at seams or around rivets
____Moderate infiltration, exfiltration
____Minor ponding of water or soil due to joint failure

3___Two or more joints open exposing one edge of band and backfill material
____Faulting of one or more joints greater than 2"
____Pipe seams open exposing backfill
____Appreciable infiltration, exfiltration
____Moderate ponding of water or soil due to joint failure

2___Severe infiltration, exfiltration
____Appreciable ponding of water or soil
____Severe seam failure

1___Severe faulting of all joints
____Pipe partially filled causing improper flow

0___Failure of pipe due to joint or seam failure

ALIGNMENT

9___Straight or smooth, new

8___Slight deflection of pipe alignment

7___Misalignment of joints ¼ to1/2" due to differential movement
____Minor deflection of pipe alignment ¼ to ½" in 10' length

6___Misalignment of joints ½ to 1" due to differential movement
____Moderate deflection of pipe alignment without ponding water, ½ to ¾ " per 10' length

5___Misalignment of joints 1" to 2" due to differential movement
____Significant deflection of pipe alignment, ¾ to 1" per 10' length
____Minor ponding of water or soil

4___Misalignment of jointsgreater than 2" due to differential movement
____Appreciable deflection of pipe alignment 1" to 2" per 10' length\
____Moderate ponding of water or soil

3___Major deflection of pipe alignment, 2 to 4" per 10' length
____Significant ponding of water or soil

2___Advanced deflection of pipe alignment, 4 to 6" per 10' length
____Advanced ponding of water or soil causing some flow constrictions

1___Alignment severe enough to impede proper flow, greater than 6" per 10' length
____Pipe partially filled from ponding of water or soil

0___Failure of pipe due to alignment failure causing back-up or flooding

CMP Rating

RCP RATING

District_______________

County_______________

Route_______________

Log Mile from Nearest

Location_______________

GPS Coordinates_________

____

Inspector_______________

Date_______________

Date of Installation_______

Type_______________

FLOW RATE

Light_________

Medium_______

Heavy_________

ABRASIVE LOAD

7___No abrasive load

6___Silt

5___Silt with sand

4___Sand

3___Sand with gravel

2___Gravel

1___Gravel with rock

0___Rock

Under notes, any item of interest such as soil types are are/not congruent with geographical area, high foliage or buildings blocking pipe from ultraviolet radiation, is culvert near processing, petroleum or other chemical substance not natural to surroundings? Etc.etc.

NOTES:____________________

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(Include surficial material on first initial inspection.)

Crossroad Y N

Re-Test Date_______________

Re-Test Date_______________

Re-Test Date_______________

Re-Test Date_______________

Pipe ID#_______________

Test Sect._______________

CRACKS AND CONDITIONS

9___No cracking

8___Fine or short cracks in end sections

7___Short or fine cracks in barrel sections
____Full coarse crack in an end section

6___One barrel section with a full fine crack
____One full coarse crack in each end section

5___Two barrel sections with full fine cracks
____One full open crack in an end section

4___One or two sections with full coarse cracks
____Three or more sections with full fine cracks
____One full open crack in both end sections plus other cracks coarse or fine

3___Two or more sections with two full coarse cracks
____One or more sections with three or four full coarse cracks
____One or more sections with one full open plus one full coarse crack
____One or both end sections broken into 4 or more pieces by open cracks

2___One or more sections with three or four full cracks at least two of which are open, seperating pipe into two or more pieces, still in place
____Slight shortening of vertical diameter
____Faulting of cracks in any section

1___One or more sections broken into four or more separate pieces by open cracks
____Pieces of sections loose or missing allowing undercutting or infiltration of fill

0___Culvert in need of immediate replacement

JOINT CONDITION

9___All joints tight

8___One or more joints loosened less than ½ depth of bell and spigot

7___One intermediate joint loosened greater than ½ depth of bell and spigot
____Both end joints loosened less than ½ depth of bell and spigot

6___Two intermediate joints loosened greater than ½ depth of bell and spigot
____One end joint loosened greater than ½ depth of bell and spigot
____Slight cracking of bells or spigots
____Minor infiltration, exfiltration

5___Three intermediate joints loosened greater than ½ depth of bell and spigot
____Both end joints loosened greater than ½ depth of bell and spigot
____One end joint open
____Minor cracking of bells or spigots
____Moderate infiltration, exfiltration
____Faulting of one or two joints less than 1"

4___Four or more intermediate joints loosened greater than ½ depth of bell and spigot
____Both end joints open exposing backfill
____One end joint faulted less than 2"
____Moderate cracking of bells or spigots
____Appreciable infiltration, exfiltration
____Faulting of one or two intermediate joints greater than 1"

3___One intermediate joint open exposing backfill
____Both end joints deflected over 2"
____Significant cracking of bells or spigots
____Major infiltration, exfiltration
____Faulting of three or more intermediate joints greater than 1"

2___Two or more intermediate joints open, exposing backfill
____End sections separated and dropped
____Water ponding because of dislocation at joints
____Severe cracking of bells or
____Advanced infiltration, exfiltration
____Faulting of one or more intermediate joints greater than 2"

1___Deflection of intermediate joints causing severe ponding of water or soils
____Pipe partially filled causing significant flow problems
____Several sections dropped at ends of pipe

ALIGNMENT

9___Straight or smooth, new

8___Slight deflection of pipe alignment, local areas less than ¼ " in 10' length

7___Misalignment of joints ¼ to ½" due to differential movement
____Minor deflection of pipe alignment ¼ to1/2" in 10' length

6___Joints misaligned ½ to 1" due to differential movement
____Moderate deflection of pipe alignment ¾ to 1" per 10'

5___Joints misaligned 1" to2" due to differential movement
____Significant deflection of pipe alignment, ¾ to 1" per 10'
____Minor ponding of water or soil

4___Joints misaligned greater than 2" due to differential movement
____Appreciable deflection of pipe alignment, 1" to 2" per 10'
____Moderate ponding of water or soil
____One end section open and slightly dropped

3___Major deflection of pipe alignment, 2 to 4" per 10'
____Significant ponding of water or soil
____Both end sections open and slightly dropped

2___Advanced deflection of pipe alignment, 4 to 6" per 10'
____Advanced ponding of water or soil causing flow restrictions
____One or both end sections out of position

1___Alignment severe enough to impede proper flow, greater than 6" per 10' length
____Pipe partially filled from ponding of water or soil

0___Failure of pipe due to alignment failure causing back-up or flooding

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